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Body Composition, Physical Activity and VO_2max in Untrained Adolescents

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Abstract

Decreased physical activity and increased adolescent sedentary lifestyles have become global cardiovascular fitness issues. Unbalanced body composition contributes to low cardiovascular fitness and increases the risk of metabolic disorders. This study aims to analyze the relationship between body composition and physical activity on VO_2max in untrained adolescents. This observational analytical study with a cross-sectional design was conducted on untrained adolescents aged 15-18. Body composition was measured using the Xiaomi Body Composition Scale S400. Physical activity levels were measured using the International Physical Activity Questionnaire (IPAQ). VO_2max was measured using the Multistage Fitness Test. Physical activity significantly contributed to in untrained adolescents (r=0.675; p=0.000). Total body water had the strongest positive correlation with VO_2max (r=0.474;p=0.003), followed by percentage muscle mass (r=0.413;p=0.010) and bone mineral (r=0.401;p=0.013). Body Mass Index (r=-0.418;p=0.009), percentage body fat (r=-0.412;p=0.010), muscle mass (r=-0.403;p=0.012), fat-free mass (r=-0.401;p=0.012) and Basal Metabolic Rate (r=-0.401;p=0.013) showed significant negative correlation with VO_2max. Increasing physical activity and improving body composition are key strategies to increase VO_2max in adolescents. Interventions involving schools, families, and the community are needed to promote an active lifestyle in this population. The results of this study provide a scientific basis for the development of effective and sustainable fitness programs.

How to Cite

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INTRODUCTION

Adolescence is the age of transition from childhood to adulthood. In this phase, adolescents face physical and psychological changes and demands. One of the significant changes in adolescence is lifestyle changes. Lifestyle changes can affect self-perception, identity exploration, and adopting healthy behaviors that influence long-term (Sluijs, Ekelund, & Crochemore-silva, 2022). Adolescent lifestyle choices will have an impact on their level of physical activity, which is often referred to as increased sedentary behavior. Low physical activity levels can increase the risk of non-communicable diseases in the future (Shao & Zhou, 2023). Based on research Andriyani, et al in 2020, most adolescents in Indonesia show low levels of physical activity, with only 12.2% to 52.3% of adolescents engaging in "sufficient" physical activity. The prevalence of sedentary behavior among adolescents was 24.5% to 33.8%, spending three or more hours per day in sedentary physical activity. Physical inactivity and sedentary behaviors are associated with various health risks, including obesity, diabetes, and cardiovascular disease(Larrinaga-Undabarrena et al., 2022) .

Low adolescent physical activity is associated with increased fat mass and negatively affects body composition and physical fitness. Physical activity is essential in maintaining optimal body composition and physical fitness, regardless of weight status (Mateo-Orcajada, González-Gálvez, Abenza-Cano, & Vaquero-Cristóbal, 2022). Active adolescents show lower fat mass, greater muscle mass, and better physical performance than adolescents with low physical activity (Joensuu et al., 2021). Body composition in adolescents is a significant indicator of health because it can indicate the risk of developing chronic diseases in the future. Changes in body composition during this period can alter hormonal and metabolic status in adolescents (HW, PL, & AF, 2020). Increased body fat can lead to higher levels of insulin and leptin. These are hormones that play a role in influencing hunger and energy expenditure. This can potentially cause metabolic disorders (Brener et al., 2021).

Adolescence is a critical period for growth and development. Optimal body composition plays a vital role in supporting the physical changes in adolescence, including the development of muscle mass and bone density (Kim, Kim, & Chung, 2020). Physical activity involves movement that requires energy to affect the body's fat proportion. Regular physical activity will also increase muscle mass so adolescents have optimal body composition (Moreno-Díaz, Vaquero-Solís, Tapia-Serrano, & Sánchez-Miguel, 2024). In addition, physical activity and optimal body composition significantly impact cardiorespiratory endurance, which is generally measured by VO_2max (Burden, Weedon, Turner, & Whaymand, 2022). VO_2max measures the maximum amount of oxygen a person can use during intense exercise. VO_2max reflects a person's level of aerobic fitness and is a crucial indicator of cardiovascular health (Neikrug et al., 2021).

Building a good VO_2max during adolescence can be the basis of lifelong fitness habits. Physical activity is essential in improving VO_2max through various physiological adaptations, including increased aerobic capacity, muscle efficiency, cardiac function, and capillary growt (Guo et al., 2024). Allocating more time for physical activity can increase VO_2max in absolute and relative terms. This is especially important for adolescents who are still in the process of developing their physical abilities (Wang, Tian, Hu, & Luo, 2023). VO_2max will increase along with the process of growth and development, regardless of gender and training status. This means that when adolescents age, their VO_2max will increase, but regular physical activity can accelerate this increase (Runacres, MacKintosh, Chastin, & McNarry, 2023). Encouraging adolescents to engage in physical activity in the form of regular exercise is an effort to build a foundation for a healthier future because it can increase VO_2max and lower the risk of non-communicable diseases, especially those related to the cardiovascular system (Mohajan & Mohajan, 2023).

Based on data from the Ministry of Youth and Sports, adolescents in Indonesia who do regular physical activity 3 times/week or more are 35.7%. Adolescents who exercise for 30 minutes or more amounted to 37.7%. This shows that the percentage of physical inactivity among adolescents in Indonesia is alarming, as it contributes to the increasing rates of non-communicable diseases such as obesity, diabetes, and hypertension. This trend highlights the urgent need for increased physical activity among youth. In addition, physical fitness measurements of 3,820 adolescents aged 16-30 years in 34 provinces in 2023 showed that adolescents with physical fitness in the excellent category amounted to 5.04%. Adolescents with physical fitness in the poor categories are 83.55%. There is a correlation between participation in physical activity and overall physical fitness in adolescents.

In this modern era, lifestyle changes and

increased dependence on technology have resulted in low physical activity in adolescents, especially those not involved in formal exercise programs. Untrained adolescents tend to have sedentary lifestyle habits, which results in body composition changes that may hinder aerobic capacity development. Few studies examine the relationship between body composition and physical activity and its effect on VO_2max, specifically in untrained adolescents. Therefore, this study aims to examine the relationship between body composition and physical activity level on VO_2max in adolescents. The results of this study are expected to provide basic information for developing intervention programs aimed at improving cardiovascular fitness in adolescence and reducing the risk of cardiovascular disease development in the future.

METHODS

This research is analytic observational research with a cross-sectional design. The subjects of this study were male dormitory students of MAN 1 Pekanbaru, totaling 38 people, who were taken using the purposive sampling technique. The inclusion criteria in this study were male subjects aged 15-18 years and adolescents willing to become respondents and were interviewed cooperatively. The exclusion criteria in this study are subjects on a diet and taking anti-inflammatory drugs, adolescents trained or active in extracurricular sports activities, suffering from acute or chronic diseases, and having muscle disorders or injuries. The dependent variable in this study is cardiorespiratory endurance (VO_2max), and the independent variables are body composition (Body et al., percentage of body fat, muscle mass, percentage of muscle mass, fat-free mass, total body water, bone mineral, Basal Metabolic Rate) and physical activity. The Health Research Ethics Commission of the Faculty of Medicine, Muhammadiyah University of Surakarta, gave ethical clearance in this study.

If Measurement of body composition in this study using the Xiaomi Body Composition Scale S400 scale is carried out by standing on the scale, making sure both feet are on the sensor part of the scale, and looking straight ahead. Before that, ensure the scale is connected to the Mi Fit application and enter personal data such as name, age, gender and height. Wait a few seconds for the circle on the scale layer to fill up, and respondents will be invited to get off the scale. The measurement results will be stored in the app in detail. Height is measured using microtoise by asking the subject to stand upright with the top of the microtia just above the subject's head. Make sure the subject's feet are tight and flat on the floor, the head touches the wall surface, the gaze is straight ahead, and the back position is upright with the shoulders not leaning forward or backward. Pull the height measuring microtoise until it touches the subject's head and read the measurement results. Physical activity was measured using the International Physical Activity Questionnaire (IPAQ), conducted by interviewing and filling out a questionnaire. VO_2max was calculated using the "bleep test" or Multistage Fitness Test (MFT) by running back and forth at a distance of 20 meters following the rhythm of the "bleep" sound on the sound player at a speed increasing over time until the participant could no longer follow the rhythm of the bleep sound. After the subject cannot follow the rhythm of running time, record the level and return, and then the results can be interpreted according to the bleep test norm.

Data collected in this study were analyzed using the SPSS 21 program. Normality of data distribution was carried out by the Shapiro-Wilk test. Univariate analysis was conducted to describe the characteristics of each variable in this study, the data in this study were ratio scale. Bivariate analysis in this study used Pearson correlation test to see the relationship between body composition and physical activity on VO_2max in untrained adolescents.

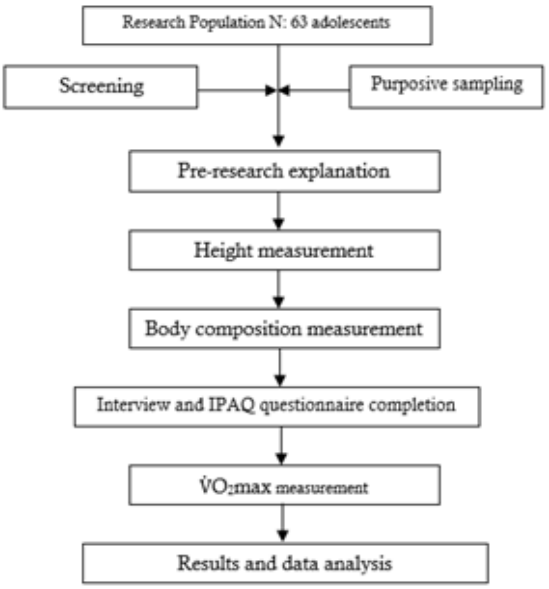

Figure 1. Research flowchart.

RESULTS AND DISCUSSION

This study analyzed the relationship be-

tween body composition and physical activity with VO_2max in untrained adolescents. Body composition data consisted of Body Mass Index (BMI), percentage of body fat, muscle mass, percentage of muscle mass, fat-free mass, total body water, bone mineral and Basal Metabolic Rate (BMR). Physical activity was analyzed based on the level of intensity and duration. The subjects in this study were all male, with an average subject age of 17 years (42.1%). The results of the research conducted on 38 untrained adolescents can be seen in **Table 1**.

Table 1. Respondent Characteristics

Variable	Measurement Result
Age	16.55±0.79(15,00-18,00)
Body Composition	
Body Mass Index (BMI) (kg/m²)	23.02±5.55(13.40-37.30)
Body Fat Percentage (%)	16.29±8.51(3.00-34.20)
Muscle Mass (Kg)	49.22±7.59(33.90-67.30)
Percentage of Muscle Mass (%)	79.38±8.06(62.50-91.90)
Fat Free Mass (Kg)	51.92±8.02(36.10-71.00)
Total Body Water (%)	58.64±7.15(44.50-79.10)
Bone Mineral (%)	4.33±0.98(3.40-5.90)
Basal Metabolic Rate (BMR) (kkal)	1492.00±173.80(1152.00-1904.00)
Physical Activity (MET)	605.63±97.03(351.00-810.00)
VO_2max (mL/kg/min)	27.58±4.22(20.80-39.90)

Table 1. Characteristics of body composition, physical activity, and VO_2max in untrained adolescents. Data are presented as mean ± standard deviation (SD), with minimum-maximum range in parentheses. BMI: Body Mass Index; BMR: Basal Metabolic Rate; MET: Metabolic Equivalent of Task; VO_2max: Maximal oxygen consumption.

Table 1 shows that the average body mass index is 23.02 kg/m2, including the categories of thin, normal, overweight, and obesity. Body mass index is associated with future health risks. Adolescents with a disproportionate body mass index will have lower muscle strength and be associated with future health problems (Scurt, Scurt, Balint, & Mijaica, 2022). This study's average muscle mass and percentage of muscle mass were 49.22 kg and 16.29%. Muscle mass plays a vital role in energy metabolism and is the leading site for energy production during exercise, essential for maintaining physical performance (Dobrowolska, Domagalska-Szopa, Siwiec, & Szopa, 2022). The subjects' average per cent body fat, fat-free mass and total body water were 16.20%, 51.29 kg and 58.64%. Body composition, including lean and fat mass, is essential for adolescent bone health. In addition, balanced body proportions also help maintain optimal growth and support long-term health in adolescents (Bim et al., 2022).

Current trends in adolescent physical activity are characterized by decreasing physical activity and high inactivity (Pinto, Marques, & Pelegrini, 2023). This highlights a critical health issue as most adolescents do not engage in sufficient physical activity. The average physical activity of the subjects in this study was 605.63 METs. These results indicate that most subjects have moderate to low physical activity levels. At the same time, The average VO_2max of the subjects in this study was 27.58 mL/kg/min, which was in the low category. This parameter is a crucial indicator of cardiorespiratory fitness that reflects the efficiency of the heart, lungs and muscles in distributing and utilizing oxygen. Low VO_2max levels in untrained adolescents may indicate potential health risks, including obesity and cardiovascular disease. Monitoring VO_2max can help early identification of these risks and assist adolescents in understanding their fitness levels (Liang & Yu, 2022).

Body Composition and VO_2max

Body composition, especially body fat percentage, can significantly affect VO_2max, the maximum amount of oxygen the body can use during intense exercise (Gonçalves et al., 2021). The body fat and lean mass ratio plays a vital role in determining VO_2max. Excess fat requires more oxygen to sustain physical activity, thus reducing efficiency in oxygen utilization during exercise (Mercê et al., 2021). When entering adolescence, proportional changes in body composition can lead to an increase in aerobic capacity. The relationship between body composition and VO_2max in this study can be seen in **Table 2**.

Table 2. Relationship between Body Composition and VO_2max

Variable	Correlation	
	p	r
Body Composition		
Body Mass Index (BMI) (kg/m²)	0.009**	-0.418
Body Fat Percentage (%)	0.010**	-0.412
Muscle Mass (Kg)	0.012*	-0.403

Percentage of Muscle Mass (%)	0.010**	0.413
Fat Free Mass (Kg)	0.012*	-0.401
Total Body Water (%)	0.003**	0.474
Bone Mineral (%)	0.013*	0.401
Basal Metabolic Rate (BMR) (kkal)	0.013*	-0.401

Table 2. Relationship between body composition and VO_2max in untrained adolescents. The p value indicates the level of statistical significance: $p < 0.01$ is marked with ** (highly significant) and $p < 0.05$ is marked with * (significant). A positive correlation (+) indicates a unidirectional relationship, while a negative correlation (-) indicates an opposite relationship.

Table 2 shows the results of correlation analysis between various body composition parameters and VO_2max in untrained adolescents. The study showed that Body Mass Index (BMI), percentage of body fat, muscle mass, percentage of muscle mass, fat-free mass, total body water, bone mineral and Basal Metabolic Rate (BMR) had a significant relationship with VO_2max ($p<0.05$). The correlation coefficients (r) ranged from -0.401 to 0.474, indicating the strength of negative and positive correlations in the moderate category. The negative correlation coefficient showed that an increase in these components tended to be followed by a decrease in VO_2max, with BMI and body fat percentage having the most robust correlation coefficients (r=-0.418 and r=-0.412). Positive correlation coefficients indicated an increase in muscle mass percentage, total body water and bone mineral, followed by a rise in VO_2max.

The results in this study are in line with research conducted Bhattachar et al in 2023 on healthy adolescents in India who did not move much; the results explained that there was a significant negative correlation between the percentage of body fat and VO_2max which means that when the rate of body fat increases, VO_2max tends to decrease. Higher body fat can reduce the body's efficiency in using oxygen during physical activity. Excess fat mass can impact heart function and working muscles and affect aerobic capacity (Zhou, 2021). In this study, muscle mass had a negative correlation with VO_2max. Higher muscle mass can lead to increased oxygen demand during physical activity. This could potentially limit the efficiency of oxygen utilization and result in lower VO_2max. Muscle tissue has a different metabolism compared to other tissues. The metabolic demands of muscle tissue and the efficiency of the energy system during high-intensity activity can affect the aerobic performance of individuals, especially in those with higher muscle mass (Wu et al., 2021).

Another body composition parameter, fat-free mass, had a negative correlation coefficient in this study. The relationship between fat-free mass and VO_2max in untrained adolescents can be complex. Fat-free mass, including muscle, bone and organs, is associated with a higher basal metabolic rate. In this study, Basal Metabolic Rate (BMR) also had a significant relationship with a negative correlation coefficient to VO_2max. If BMR is high due to excess body mass, oxygen utilization efficiency may be impaired, leading to lower VO_2max. This is particularly relevant in untrained adolescents who may not have developed the cardiovascular efficiency seen in physically active individuals (Singh et al., 2023). Individuals with high fat-free mass have higher energy expenditure at rest, which may affect their overall fitness levels. In untrained adolescents, this relationship is also influenced by various factors, including physical exercise. Adolescents with high fat-free mass and low VO_2max indicate their bodies are not conditioned or accustomed to utilizing increased muscle mass effectively during aerobic activity, and one of the things that can be done to overcome this is regular aerobic exercise (Mendonça et al., 2022).

Body composition significantly affects performance in physical activities, including V VO_2max. The negative correlation coefficient between muscle mass and VO_2max indicates that when total muscle mass increases, oxygen consumption's relative efficiency per muscle unit may vary. This could be due to an imbalance between muscle growth and cardiovascular and metabolic adaptations. Without adequate aerobic exercise, an increase in muscle mass not accompanied by a proportional increase in oxygen capacity can lead to a decrease in relative VO_2max. This study's correlation coefficient of per cent body frailty and VO_2max was positive. This suggests that a higher proportion of muscle relative to body weight increases aerobic capacity (Lichti et al., 2023).

In this study, body composition indicators, namely total body water and bone mineral, had a significant relationship with VO_2max. Total body water is essential in maintaining hydration during physical activity, regulating body temperature and supporting metabolic functions. Adequate hydration helps maintain blood volume and cardiovascular function, which is essential for oxygen transportation during exercise. When TBW is optimal, it can support better oxygen delivery to muscles and increase VO_2max. Ensuring sufficient body water is essential for maximizing

VO_2max, as it directly affects hydration status, cardiovascular function, and oxygen transport during physical activity (Ekingen et al., 2022). Meanwhile, bone minerals in adolescents are essential because they play a crucial role in bone development, fracture prevention and long-term health (Han, Kim, & Kim, 2021).

Adolescence is a critical period for bone development where maximum bone mass is accumulated. Increasing maximum bone mass during adolescence is an effective strategy to prevent future bone health problems. Healthy lifestyle habits by actively engaging in physical activity are essential in determining bone mineral density (Simões et al., 2021). In addition, adequate calcium intake is essential for bone growth. Appropriate nutritional intake and engagement in physical activity in adolescents can maintain bone health and muscle function. Essential minerals such as calcium, magnesium, and iron support energy metabolism and muscle oxygenation, which are essential in achieving optimal VO_2max (Ghazzawi et al., 2023).

Physical Activity and VO_2max

Physical activity is a crucial component of a healthy lifestyle contributing to physical and mental well-being. Physical activity is body movement produced by skeletal muscles and requires energy expenditure. This activity includes various forms of movement ranging from daily activities to structured sports. Regular physical activity is significant for adolescents as it reduces the risk of developing cardiovascular disease in adulthood. Regular physical activity triggers various physiological adaptations that benefit the body, especially in improving cardiovascular and respiratory capabilities. These adaptations involve increasing the number and efficiency of capillaries in the muscles and improving lung capacity. In addition, the heart becomes more robust and can pump blood more efficiently. As a result, the body can work longer and harder without feeling tired quickly, which signifies improved overall fitness (Silva, de Andrade Gonçalves, Coelho, Cerqueira, & Werneck, 2022). The relationship between physical activity and VO_2max n this study can be seen in **Table 2**.

Table 3. Relationship between Physical Activity and VO_2max

Variable	Correlation	
	p	r
Aktivitas Fisik (MET)	0.000***	0.675

Table 3. Relationship between physical activity and VO_2max in untrained adolescents.The p value indicates the level of statistical significance: $p < 0.001$ marked with *** (highly significant). A positive correlation (+) indicates a unidirectional relationship.

The **Table 3** shows the results of the correlation analysis between physical activity measured by VO_2max, which is an indicator of aerobic capacity. Based on the table, there is a significant relationship between physical activity in untrained adolescents and VO_2max ($p=0.000$). This value shows a very high statistical significance ($p<0.001$). The correlation coefficient (r) in this study was 0.675, indicating a strong positive relationship between physical activity and VO_2max. This means that the higher the physical activity performed by a person, the better his aerobic capacity, which is reflected in the increase in VO_2max. These results are in line with research conducted by Arovah and Purnomo in 2022, which found that there is a positive relationship between the level of physical activity and VO_2max, indicating that higher physical activity is associated with better cardiorespiratory fitness among adolescents.

Establishing a regular physical activity routine during adolescence can lead to sustained improvements in fitness levels and health. Different types of exercise, such as aerobic exercise, resistance training and high-intensity interval training, can improve VO_2max. It is recommended that adolescents do at least 60 minutes of moderate to vigorous intensity physical activity daily to reap the health benefits and become the foundation of a healthier lifestyle into adulthood (van Baak et al., 2021). In a study conducted by Sriram et al in 2021 2021 on 9,915 adolescents aged 12 to 19 years, it was found that small increases in physical activity can lead to significant health benefits. For example, engaging in 150 minutes of moderate to vigorous physical activity each week can lower the BMI percentile by about 7% compared to those who do not engage in any physical activity.

Alarmingly, only about 20% of adolescents meet their daily physical activity recommendations. This highlights the need for increased efforts to promote physical activity among adolescents. Adolescents can engage in physical activity, including team sports (football, basketball), individual sports (swimming, running), recreational activities (cycling, dancing) and structured exercise programs (gym workouts, fitness classes). The intensity of physical activity plays an important role; moderate to vigorous physical activity is more effective in increasing VO_2max compared to light physical activity; this is because higher-

intensity exercise challenges the cardiovascular system more and leads to a greater increase in oxygen consumption (Villafaina, Tapia-Serrano, Vaquero-Solís, León-Llamas, & Sánchez-Miguel, 2021).

In a study conducted by Ellyas et al in 2021 on 60 healthy and untrained adolescents who were given High-Intensity Interval Training (HIIT) and Moderate Intensity Continuous Training (MICT) and their effect on cardiorespiratory fitness measured as VO_2max. The results of the study were HIIT increased VO_2max from 31.2 ± 5.8 to 35.5 ± 6.9 mL/kg/min ($p < 0.001$), and MICT increased VO_2max from 32.3 ± 6.8 to 37.3 ± 6.7 mL/kg/min ($p < 0.001$). There was no significant difference in the improvement of VO_2max between the two groups (p=0.292), indicating that HIIT and MICT physical activity interventions effectively improve cardiorespiratory fitness in adolescents. The study also noted that VO_2max is an important indicator of overall cardiorespiratory fitness associated with reduced risk of cardiovascular disease. Based on this, HIIT and MICT could be suitable exercise options for adolescents to improve their fitness and health.

Adolescents are expected to participate systematically in physical activity over time. Low levels of physical activity in adolescents can contribute to weight gain and obesity and are associated with various health problems, including diabetes and hypertension (Poole, Harris, & Greenough, 2023). Low physical activity will also affect VO_2max and cardiovascular health. Adolescents with low VO_2max will experience lower perceived competence in performing physical activity. This affects adolescents' willingness to engage in exercise and leads to a cycle of inactivity and further fitness decline (González-Gálvez et al., 2023). These findings highlight the importance of promoting physical activity among adolescents to increase their fitness levels, improve their risk perception, and foster an overall healthier lifestyle.

CONCLUSION

This study shows that body composition consisting of Body Mass Index (BMI), percentage of body fat, muscle mass, percentage of muscle mass, fat-free mass, total body water, bone mineral and Basal Metabolic Rate (BMR) and physical activity have a significant influence on VO_2max of untrained adolescents (p=<0.05). Physical activity made a strong contribution in influencing VO_2max (p=0.000) and showed a negative correlation. Among the body composition indicators, the percentage of muscle mass, total body water and bone mineral showed a positive correlation with VO_2max. While BMI, percentage of body fat, muscle mass, fat-free mass and basal metabolic rate had a negative correlation with VO_2max. Based on these findings, interventions to improve body composition in adolescents should focus on controlling body composition and increasing physical activity levels..

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